In the Drawings

In accordance with the Examiner's requirement, applicant submits herewith a replacement sheet containing revised Figures 4 and 5 and new sheets containing Figures 6-9.

REMARKS

Petition for Extension of Time Under 37 CFR 1.136(a)

It is hereby requested that the term to respond to the Examiner's Action of October 31, 2006 be extended three months, from January 31, 2007 to April 30, 2007.

Authorization to charge a Credit Card is given to cover the extension fee. The Commissioner is hereby authorized to charge any additional fees associated with this communication to Deposit Account No. 19-5425.

In the Office Action, the Examiner indicated that claims 1 through 10 are pending in the application and the Examiner rejected all claims. Applicant has cancelled claims 1-10 and added new claims 11-50.

Examiner Interview

On March 19, 2007, the Examiner kindly conducted an in-person Examiner Interview with the Applicant, by its counsel Peter Langley and Mark Simpson (the undersigned). Applicant thanks the Examiner for considering its comments and in keeping with the Examiner's comments during the interview, Applicant has presented new claims that include critical features explicitly stated to distinguish the invention from the prior art.

Objections to the Drawings

On page 3 of the Office Action, the Examiner has objected to the drawings for failing to show every feature of the invention specified in the claims. Specifically, the Examiner has required that

the terms "virtual point light source," "line light source," "opening per cell," "movable mirror," "another suitable way," and "position sensor" must be shown or the features canceled from the claims.

Applicant herewith submits revised Figures 4 and 5, and new Figures 6 through 9.

Applicant submits the following in response to the Examiner's objections:

"Virtual point light source" is shown in new Figure 6 (virtual point light sources 61 and 64 are shown);

"Line light source": The light sources in Figures 1, 2, 3, 5, and 6 may be point sources, or they may be line-shaped light sources shown in cross-section, as would be appreciated by one skilled in the art. In the application, "line light source" has been revised to "line-shaped light source," which is a better translation of the original German language PCT publication.

"Opening per cell": The possible three openings per cell are shown in new Figure 8.

"Movable mirrors": Movable mirrors 60 and 70 are shown in new Figures 6 and 7.

"Another suitable way" has been deleted from the Claim language.

"Position sensor" is included in new Figure 9. Such sensors are well known. Examples can be obtained by typing '"Viewer Position Sensor"' into Google, as shown in the attached Exhibit 1.

The §112 Rejections and Claim Objections

On page 4 of the Office Action, the Examiner has rejected claims 1-10 under 35 U.S.C. §112, first paragraph, as filing to comply with the enablement requirement. Also on page 4, the Examiner

has objected to claims 1-10 for various informalities. Applicant has cancelled claims 1-10, rendering the Examiner's rejection and objections moot. However, Applicant has addressed the issues raised by the Examiner in the newly-added claims.

Claim Rejections, 35 U.S.C. § 103

On page 6 of the Office Action, the Examiner rejected claims 1, 2, 7 and 8 under 35 U.S.C. §103(a) as being unpatentable over U.S. Patent No. 7,053,925 to Payne et al. On page 8 of the Office Action, the Examiner has rejected claims 3-6 under 35 U.S.C. §103(a) as being unpatentable over Payne and further in view of U.S. Patent No. 6,665,100 to Klug et al., and on page 9 of the Office Action, the Examiner has rejected claims 9-10 under 35 U.S.C. §103(a) as being unpatentable over Payne and further in view of U.S. Patent No. 6,462,869 to Gutjahr.

Since new claims have been submitted to replace the rejected claims, the rejection of the claims based on Payne and/or Klug and/or Gutjahr is effectively rendered moot. However, Applicant addresses the primary reference cited by the Examiner (Payne) art and the novelty and non-obviousness of the new claims below.

Steps (a), (b) and (c) of newly added claim 11 are each independently new and inventive steps. No specific sequence of operations should be implied by denominating the stages as (a) – (c).

(a) controlling the spatial light modulator specifically so that the wavefront is associated with a virtual observer window at which an observer places at least one eye in order to view the entire holographic reconstruction, the step of controlling the spatial light modulator resulting in the virtual observer window being constrained to be substantially at the image

plane of the light source;

In a conventional, prior art electro-holographic reconstruction, the observer can see a holographic reconstruction of an object so long as he is inside a viewing cone; but his distance from the hologram is *not relevant*. In conventional holography, the holographic reconstruction is at or near the image plane of the light source illuminating the hologram and it has the same far-field light distribution of the real world object that is reconstructed. Consequently, the observer can be *any* distance from the reconstruction and yet still see it properly (so long as he is within the conic section shaped viewing zone).

For example, US 7053925 **Payne** teaches that:

> "Another feature of CGH based displays is the viewing region, the bounds of which are shown by dashed lines (29). This is the region in which the eye needs to be located in order to see the whole image." Col 9, lines 7 – 11.

Also:

> "the apparatus allows the effective exit pupil to be of arbitrary shape and size and to be **arbitrarily positioned** in all **three** dimensions" col 5 lines 6 – 8 of Payne.

Further, in Fig. 3 of Payne, eye pupil 33 is clearly not in the image plane of the light source, which is plane 22 of Figure 2 or 32 in Figure 3 (see the focus points 34). If the eye pupil 33 were to be placed at focal plane 32 of Payne, then no reconstructed image would be seen.

Hence, entirely absent from Payne is the approach of encoding the spatial light modulator (SLM) so that the entire reconstruction can be seen through a virtual observer window *constrained to be substantially at the image plane of the light source*. In fact, Payne envisages the observer being at

any arbitrary z distance (so long as he or she is within the viewing region (29 of Figure 2)). As is clear from Payne column 9, lines 7 – 11, the reconstruction will not be seen if the observer places his eyes at the image plane 22/32.

Method step (a) defines a very different arrangement in which the reconstructed object is not at the image plane of the light source illuminating the hologram at all. Instead, the SLM is encoded in such a way that a virtual observer window is constrained to be substantially at the image plane of the illuminating light source; the observer positions his eye or eyes at this location and only then can a correct, entire reconstruction be seen.

The reason the SLM is encoded so as to constrain the eye position is most easily understood from the preferred implementation. In the preferred implementation, the hologram is encoded on an SLM and the SLM is illuminated so that the wavefront at the virtual observer window becomes the Fourier transform of the wavefront at the SLM (hence a Fourier transform defines what is imaged directly onto the eyes)[1]. It is therefore desirable to *constrain* the distance of the virtual observer window from the SLM, as defined in step (b), because the challenge is to control the wavefront at the

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[1] Fourier transforms are merely approximations to physical processes more accurately defined by Maxwellian wave propagation equations; Fourier transforms are second order approximations, but have the advantages that (a) because they are algebraic as opposed to differential, they can be handled in a computationally efficient manner and (ii) can be accurately implemented in optical systems.

eyes in a very exact way. Only substantially at the image plane is the wavefront defined by the well known Fourier transform – at positions significantly closer or further way from the spatial light modulator than the image plane, more complex parametric equations need to be used. The preferred implementation will use the Fourier transform (and not more complex parametric equations). Hence, as the observer moves substantially closer to or away from the image plane, the quality of the holographic reconstruction will deteriorate and eventually disappear entirely because the wavefronts reaching the eyes are not those wavefronts needed for an accurate holographic reconstruction; with increasing distance from the image plane the observer will perceive increasing contributions stemming from outside of the reconstruction volume.

It should be noted that Claim 11 does not require that the virtual observer window can *only be exactly* at the image plane of the light source. It instead requires that the encoding of the SLM is such as to generate a virtual observer window that is constrained to be substantially at the image plane of the light source. We therefore define the SLM encoding/controlling step in terms of the result it achieves; this is independent of whether an observer is actually present and where that observer places his or her eyes.

So in this preferred implementation, for computational efficiency, the encoding is such as to place the viewing plane substantially at the image plane of the light source, because the wavefronts reaching the eyes can then be readily controlled since they will be defined by the Fourier transform of the wavefronts at the SLM. Encoding to achieve this result is not a step that occurs in Payne or any other known prior art. In conventional holography, there is no concept of the desired wavefronts at the eye position being sensitive to distance from the image plane – quite the opposite is the case

because in conventional holography, the eye is simply in the far field zone and hence can be at *any* distance from the image plane of the light source. In conventional holography, high-resolution spatial light modulators are used with the primary goal to reconstruct the object. The eye is inside a viewing cone and can be at *any* distance from the image plane of the light source.

Step (b) limiting the size of the virtual observer window to be no larger than a single diffraction order of the light diffracted from the spatial light modulator, the pitch of the spatial light modulator determining the maximum size of the virtual observer window and not the maximum size of the holographic reconstruction because the virtual observer window is substantially at the image plane of the light source;

This step is also novel and non-obvious. A fundamental limitation facing designers of holographic video systems is the pixel pitch of the LCD (or other kind of light modulator). The present invention enables large holographic reconstructions using LCDs with pixel pitches that are commercially available at reasonable cost. In the past this has been impossible for the following reasons. First, spatial light modulators that are regularly structured generate multiple, periodic diffraction orders. The periodicity interval between adjacent diffraction orders in the Fourier plane (i.e. the image plane of the light source) is given by $\lambda D/p$, where λ is the wavelength of the illuminating light, D is the distance from the hologram to the Fourier plane and p is the pixel pitch of the LCD. But in conventional holographic displays, the reconstructed object is in or near the Fourier plane, as noted above. Hence, a reconstructed object has to be kept smaller than the periodicity interval; if it were larger, then its edges would blur into reconstructions from adjacent diffraction orders.

This leads to very small reconstructed objects in the prior art – typically just a few cm across, even with costly, specialized small pitch displays.

For example, in Payne:

"The three dimensional image will typically be contained within a diamond shaped (polyhedral in three dimensions) volume (23). Col 8 lines 65 – 67.

This is typical of conventional holographic systems, in which the reconstructed image is contained within a small volume centered around the focal plane of the imaging optics. A necessary consequence is that the pitch of the spatial light modulator determines the maximum size of the holographic reconstruction and has no bearing on the maximum size of any virtual observer window. This is the exact *opposite* of the present invention.

With the present approach, it is the virtual observer window that is positioned to be in the image plane of the illuminating light source (i.e. the Fourier plane) and hence it is the virtual observer window that should preferably be kept smaller than (or equal to) the periodicity interval. But this virtual observer window need only be as large as the eye pupil, so this requirement is relatively easily met. As a consequence, even LCDs with a moderate pitch size, e.g. leading to a 1 cm periodicity interval at the image plane of the light source, can be used for holographic reconstruction, because 1 cm exceeds the typical diameter of the human eye pupil.

Step (c) forming the holographic reconstruction anywhere within a reconstruction volume spanned by the spatial light modulator and the virtual observer window.

This step is also novel and non-obvious. In a conventional holographic system, the size of the reconstructed object is limited by the periodicity interval between adjacent diffraction orders, as

explained above in relation to Claim 1, step (b). For even a high performance LCD giving a periodicity interval of 1cm, the reconstructed object can in effect be no larger than $1cm^2$ in cross section and is constrained to a small volume centered around the focal plane of the imaging optics. For example in Payne:

> "The three dimensional image will typically be contained within a diamond-shaped (polyhedral in three dimensions) volume (23). Col 8 lines 65 – 67.

But with the present invention, the 1cm periodicity interval limits the size of the virtual observer window, and not the size of the reconstructed object, as noted above. The reconstruction can appear anywhere between the virtual observer window and the LCD. Because the reconstructed object can entirely fill a reconstruction volume spanned by the viewing window and the spatial light modulator, it can be very large indeed. The applicant has constructed a prototype using a 20", commercially available LCD as the SLM. This can generate holographic reconstructions appearing in front of the SLM that can be as wide as 20"; reconstructions positioned behind the SLM can be even larger.

The present invention hence solves a fundamental problem that has beset reconfigurable holographic reconstruction for decades – namely how to generate a large reconstruction. The present invention not only solves this problem, but it does so using commercially available LCDs.

Conclusion

The present invention is not taught or suggested by the prior art. Accordingly, the Examiner is respectfully requested to reconsider and withdraw the rejection of the claims. An early Notice of Allowance is earnestly solicited.

Included herein is a Petition for extension of time to respond to the Examiner's Action, and authorization to charge the extension fee to a credit card. The Commissioner is hereby authorized to charge any additional fees or credit any overpayment associated with this communication to Deposit Account No. 19-5425.

Respectfully submitted

April 30, 2007
Date

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